UNITED STATES DEPARTMENT OF AGRICULTURE

BUREAU OF ENTOMOLOGY

FOREST INSECT INVESTIGATIONS

A PROPOSED TREE CLASSIFICATION FOR THE SELECTION FORESTS OF THE SIERRA NEVADA, CALIFORNIA WITH SPECIAL REFERENCE TO WESTERN YELLOW PINE, PINUS PONDEROSA LAWS

by

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April 8, 1927

U. S. GOVERNMENT PRINTING OFFICE, 1926 J 70133

4/8/27

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Individuality in man is accepted without question. In domestic animals, also, good and bad individuals are generally recognized. Even in some cultivated plants, - orange trees, rubber trees, - the poor producers are searched out and eliminated. Indeed, individual variability is a normal condition in all groups of organisms. Yet forest trees are rarely thought of in terms of the individual. Forest products are seldom of sufficient value to justify tending the individual tree. But there is no more reason why two western yellow pine trees should grow with equal rapidity or bear equal amounts of seed because they grow under identical conditions, than that two men should attain equal strength or equal mentality because they receive the same food. When to inherent variability is added the effects of a wide range of inter-related environmental factors, the great differences in the behavior of individual trees can be readily appreciated. It is adjudged a ~~common~~ fault to lose sight of the forest through confusion of the trees. Much more frequently the mass effect is the more obvious and there is failure to see in their proper relationships the elementary components of the forest - the trees.

Existing Tree Classifications

Within the species foresters have necessarily been limited to slightly less generalized groups of individuals defined by differences in vigor or value. Dominant, codominant, intermediate, and suppressed, or some such classes of trees, are universally recognized. In European countries where forestry has become most intensive, the necessity of distinguishing these differences in vigor and value more clearly has led several foresters to consider not only position in the crown canopy but crown development and stem form as well.

In Germany in 1884, G. Kraft formulated a tree classification based on crown development (6) [1]. This was amplified by C. R. von Heck in 1897 by distinguishing stem classes within each crown class (4). Marked differences in growth (8) and seed bearing (15) between these tree classes have been clearly demonstrated through the study of sample plots over long periods.

In 1902 German forest research institutions agreed upon a tree classification to be used in thinning research (9). In Switzerland, France, Denmark, Finland and Sweden the question of tree classes is also dealt with extensively in the literature of thinning. The late Gunnar Schotte, in the publication of the Swedish state forest experiment station in 1912, gave a review of tree classifications hitherto in use and added one of his own, based partly upon position in the crown canopy, partly upon crown development, and to a lesser degree upon stem form (12) (8).

1. Numbers in parenthesis refer to literature listed.

The Need for a New Classification

All these classifications, so far as known, apply to even-aged stands, for the most part well stocked, and of comparatively simple composition. In the pine stands of California the situation is complicated by irregularity in age, under-stocking, and mixtures of several tolerant and intolerant species. In addition to position in the crown canopy, crown development and stem form, the age of each tree must be considered in grouping according to capacity for growth and seed production. The conventional dominance classification applicable to even-aged stands, if recognized at all, is an unsatisfactory index of vigor under these conditions. In the yellow pine stands of the Southwest some improvement is effected by recognition of two broad age classes - "black-jacks" and "yellow pines" (7). In California a rough segregation of age classes is now practiced in marking, but is recognized to be inadequate. Selection by diameter limits is a poor makeshift to be used only when selective marking is not feasible.

The history of older Forest Service cuttings and recent examinations of marking on several of the most important sales indicate clearly that there is still lack of reasonable uniformity in the application of the same marking principles in similar stands. Incorrect marking has frequently resulted in rates of growth much below the capacity of the sites. Far too many unproductive trees are being retained.

The policy of the Forest Service in this region is to reserve twenty to thirty per cent of the original stand in sound thrifty trees capable of good growth, and likely to survive windfall, insect attacks, or fire, to make feasible a second cutting in comparatively inaccessible areas in reasonable time. A considerable portion of this reserve must be high quality timber which necessarily means rather large trees. As a

source of seed, in case of destruction of advance reproduction by fire, four or more seed trees per acre must be left, also of rather large size. Far more skill is demanded in marking for this large reserve than for a heavy selection or seed tree cutting. In many cases the provision for reservation of a certain percentage of the stand has been too strictly adhered to with insufficient consideration to condition of the stand or variations in site.

A recognized system of tree classification would no doubt result in more uniform marking. As a basis for comparison of marking jobs in sales inspections such a system has obvious advantages.

Forest entomologists have demonstrated that the western pine beetle has a definite tendency to select certain trees under conditions of endemic infestation. A clear definition of the susceptible types of trees would permit their elimination by marking and thus obviate much of this important source of loss.

In studies of sample plots in selection stands where records are made for individual trees, a uniform system of tree classification is needed to simplify recording and permit accurate comparison of one area with another. E. J. Hanzlik has suggested using the Swedish system developed by Schotte for such work (3). For sample plots in even aged stands it doubtless works well, but omission of the age factor makes it unsuitable for application in selection stands or cut-over areas.

A workable tree classification also offers interesting possibilities in appraisals, in marking to maintain certain standards of growth, in predicting future yields, in susceptibility to fire damage and in many other ways in which simple crown classes are used in even-aged forests.

Whatever system of tree grouping is used in marking, it is not to be expected that there will be perfect agreement between different men, but adherence to a definite system of appraising each tree, based on easily discernible characteristics, will prevent obvious mistakes in marking, raise the average rate of growth in cut-over stands, decrease losses and improve the quality of seed trees. Agreement upon a well defined terminology is essential to mutual understanding.

Basis for Classification

These conclusions are the results of fifteen years observation of over 20,000 numbered trees in 26 permanent sample plots, comprising about 300 acres, established on typical sale areas in the Sierra. Detailed crown and bole descriptions permit segregation of the trees into the classes to be described below. On this basis comparisons of growth and seed bearing have been made from measurements taken at 5-year intervals. For the sake of brevity, the results for only one species, western yellow pine (*Pinus ponderosa Laws.*) are presented here. This species occurs on all the plots in numbers sufficient to give a reasonably good basis of data. It is widely known, and is more easily grouped into the proposed classes than any of the other species.

The present classification represents an effort to segregate into groups the trees with certain combinations of factors known from previous studies ~~(1)~~ (2) to have similar influences on growth or seed bearing. It is obviously impossible to consider each of the interrelated variable elements singly. The significance of any one factor cannot be isolated. Practice demands that the number of classes be small and

that the factors on which they are based be readily distinguishable. In actual field tests no serious difficulties have been encountered by men with no previous knowledge of this grouping.

The major factors considered in the make-up of these classes are: four general age groups, young (less than 50 years), thrifty mature, (50 to 150 years), mature (150 to 300 years), and overmature (over 300 years); degree of dominance within these age groups, expressed in terms of the conventional crown classes; crown development; a supplementary estimate of thrift designated in three degrees of vigor - good, moderate, and poor. The estimate of vigor is based on apparent age, degree of dominance, crown development, and in addition, the density and color of the foliage, the form of the top (whether pointed, round, or flat), the size attained in relation to age, the color, thickness and texture of the bark, and freedom from disease.

For application in marking only sound, well formed trees need be considered in such a classification. It is deemed undesirable to introduce complications by a coding for the multitude of defects which may possibly occur. The question of merchantability assumes priority and should be considered separately on the basis of already well established criteria. Trees that are malformed, injured, or diseased should be removed from the stand wherever possible and it is unnecessary to go farther in segregating them by thrift classes.

In working up this material an effort was made to determine to what extent mechanical injuries and defects, such as fire scars and logging scars on the stem, fire or logging damage to the crown, broken or dead tops, etc., affect growth. The difficulty of isolating the effects of a given class of defects is apparent. On cut-over areas the number

of defective trees has naturally been reduced so that after division into comparable groups there is insufficient material to be of much significance. Damage to the crown which materially reduces the leaf area is usually reflected by a reduction in the rate of growth. In the present data no consistent relation is discernible between mechanical injuries to the stem and deficient vigor. Such injuries, when of sufficient extent to materially affect growth, tend to induce wind breakage or infection with rot producing fungi, and should influence marking through predisposition to losses and their effect on merchantability rather than through their effect on rate of growth. In research work it has been found a simple matter to supplement the classification for sound trees by a supplemental description of defects for purposes of study, or to eliminate their uncertain influences.

Description of Classes

The seven proposed tree classes are as follows:

Class 1. Age class, young or thrifty-mature; position, isolated or dominant (rarely codominant); crown length, 65 per cent or more of the total height; crown width, average or wider; form of top, pointed; vigor, good (Plate I, fig. 1).

Trees of this class are rarely over 30 inches in diameter even on good sites. The bark is dark brown, and roughly fissured into ridges or small plates. The foliage is rich green in color and dense, owing to retention of the needles of three to five seasons or more, except at the base of the crown. The needles are often long and coarse, especially near the top. Terminal buds are large. The top is pointed, due to rapid elongation of the terminal. (Thrifty open grown young trees are some-

times round topped because of excessive lateral growth of branches near the top.) The annual wherls of branches and internodes are still distinct except in the lower crown. Branches are horizontal or upward curving, except at the base of the crown where suppression is taking place. Numerous stubs of dead branches are often present below the crown.

Class 2. Age class, young or thrifty-mature; position, usually codominant (rarely isolated or dominant); crown length, less than 65 per cent of the total height; crown width, average or narrower; form of top, pointed; vigor, good or moderate. (Plate I, fig. 2.)

Such trees are usually less than 24 inches in diameter. They are commonly the inside codominant trees of groups. The crowns are smaller and less dense than in trees of the first type. Otherwise they are similar to those of Class 1.

Class 3. Age class, mature; position, isolated or dominant (rarely codominant); crown length, 65 per cent or more of total height; crown width, average or wider; form of top, round; vigor, moderate. (Plate I, fig. 3.)

Trees ordinarily between 18 and 40 inches in diameter, depending on site quality. The bark is light brown, or yellow, in color with moderately large smooth plates. The foliage is less dense than in Class 1 trees. The top is round because of slow height growth. The nodes are indistinct because of incomplete wherls of branches. The branches are nearly all horizontal or drooping.

Class 4. Age class, mature; position, usually codominant (rarely isolated or dominant); crown length, less than 65 per cent of the total height; crown width, average or narrower; form of top, round; vigor, moderate or poor. (Plate I, fig. 4.)

These are commonly the inside, or codominant trees of this age class. Except for their small poorly developed crowns and smaller size they are similar to Class 3 trees.

Class 5. Age class, overmature; position, isolated or dominant (rarely codominant); crown of any size; form of top, flat; vigor, poor. (Plate I, fig. 5.)

These are usually the largest trees in the stand. The bark is light yellow in color, the plates often very wide, long, and smooth, especially near the base. The bark may be thin, due to weathering more rapidly than it grows. The foliage is usually rather pale green and very thin. The needles are rather short, appearing as tufts on the ends of the twigs. The needles of two or three seasons only may be retained even near the top. The top is flat, the terminal rarely discernible. There is no appreciable elongation of the main axis. Scarcely any nodes are distinguishable. Nearly all the branches are drooping, gnarled and crooked.

Class 6. Age class, young or thrifty mature; position, intermediate or suppressed; crown of any size, usually small; form of top, round or pointed; vigor, moderate or poor. (Plate I, fig. 6.)

Understory trees rarely over 12 or 14 inches in diameter. The bark is dark and rough. The top is round or pointed since some height growth is taking place. Wherls of branches are evident, though the internodes are short.

Class 7. Age class, mature or overmature; position, intermediate or suppressed; crown of any size, usually small; form of top, flat; vigor, poor. (Plate I, fig. 7.)

Understory trees rarely over 18 inches in diameter. The bark is light in color, thin and smooth. The top is flat, the terminal rarely distinguishable. The foliage is excessively thin. The few branches present are gnarled, and drooping.

The similarities and differences between these groups are perhaps more evident in an abbreviated tabular comparison:

Table I.

Class	Crown length	Crown width	Form of top	Crown Class (position)	Age class	Vigor
1	65%+	M-W		X D (C)	Y - TM	V
2	-65%	N - M		C (X-D)	Y - TM	V - M
3	65%+	M - W		X D (C)	M	M
4	-65%	N - M		C (X-D)	M	M - P
5	All	All		X D C	O M	P
6	All	All		I - S	Y - TM	M - P
7	All	All		I - S	M - OM	P

Relative Importance of Classes in the Stand

The relative importance of the tree classes in the original and remaining stand and the proportion of the cut supplied by each, are shown in the following tabular summary of a typical stand on the Stanislaus National Forest. Volume figures represent stand per acre in board feet. Marking was carefully done by a marking board to conform as nearly as possible to existing cutting policy.

Table 2.

Tree class	1		2		3		4		5		6		7		Total	
	B.F.	%	B.F.	%	B.F.	%	B.F.	%	B.F.	%	B.F.	%	B.F.	%	B.F.	%
Original stand	12772	16.6	2259	2.9	21297	27.8	1708	2.2	37875	49.4	211	0.3	595	0.8	76717	100.0
Reserved	8399	62.8	1906	14.2	2890	21.6	-	-	-	-	160	1.2	20	0.2	13375	100.0
Marked	4373	6.9	353	0.6	18407	29.1	1708	2.7	37875	59.7	51	0.1	575	0.9	63342	100.0

Classes 1, 3, and 5, the large crowned dominant trees in the three general age groups, here form 93.8 per cent of the original volume in board feet for trees 12 inches in diameter and larger. Classes 3 and 5, mature and overmature dominants provided 89.8 per cent of the cut. These tree classes contain the highest grade material (12) and probably represent more than 95 per cent of the present value of the entire stand. The Class 1 trees, immature, dominants, which formed 16.6 per cent of the original stand, supplied but 6.9 per cent of the volume cut. Such trees were marked only when necessary to thin groups, or to facilitate logging, or when badly injured by removal of other trees. Classes 1 and 2 make up 77.0 per cent of the 13375 bd. ft. per acre reserved, representing very little present value, since they contain comparatively little high grade lumber. Class 3 trees represent 21.6 per cent of the reserve volume, providing a few larger seed trees and some high grade material for a second operation.

The small-crowned dominant and codominant trees of Classes 2 and 4, and the intermediate and suppressed trees of Classes 6 and 7 always form a relatively small part of the merchantable volume. In number of trees, however, they are often relatively important. These classes are of primary interest because of their influence on future yields. The numerical importance of the tree classes in the above stand is shown below, with the inclusion of unmerchantable trees between 4 and 12 inches. In this stand where there was an average of 99.4 trees per acre, most of the trees were in Classes 1 and 6, 34.4 per cent and 37.6 per cent, respectively. Classes 2, 3 and 5 were nearly equally represented by 7 to 8 per cent of the total. There were relatively few trees in Classes 4 and 7.

Table 3.

Tree Class	1 No.	1 %	2 No.	2 %	3 No.	3 %	4 No.	4 %	5 No.	5 %	6 No.	6 %	7 No.	7 %	Total No.	Total %
Original Stand	34.2	34.4	7.6	7.7	7.3	7.3	0.5	0.5	8.2	8.3	37.4	37.6	4.2	4.2	99.4	100.0
Reserved	30.8	39.5	7.3	9.4	0.9	1.2	-	-	-	-	37.2	47.6	1.8	2.3	78.0	100.0
Marked	3.4	15.9	0.3	1.4	6.4	29.9	0.5	2.3	8.2	38.4	0.2	0.9	2.4	11.2	21.4	100.0

Comparisons of Growth

For the sake of simplicity all the following growth comparisons are in terms of basal area, expressed as average annual rates in per cent for the fifteen year period. In terms of volume growth the differences shown would be accentuated, since the mature and overmature trees make practically no height growth. The size grouping is based on the diameters at the beginning of the period.

Figure 1 permits comparison of the relative rates of growth of the seven tree types by diameter classes. The graph is based on 1183 trees growing on a first quality site cut over in 1910, Stanislaus National Forest.

The Class 1 trees are superior to the others for all diameters, especially in the smaller sizes. The Class 2 trees have grown considerably slower than those of the first group, but in the smaller size classes, are considerably above the trees in the remaining groups. Above 18 inches Class 2 and 3 trees have grown at about the same rate, the larger crown area of the Class 3 trees offsetting their greater age. The rate for the latter group shows little variation with size.

The trees of Classes 4, 5 and 7 also show little variation with diameter, growing at a hopelessly slow rate for all sizes. The younger trees of Class 6 give some promise, and the fact that few of them can be cut under present economic conditions is not a serious matter.

It is evident that a good rate of growth cannot be expected from mature and overmature trees of Classes 3, 4, 5, and 7, regardless of diameter, even on the best sites. Above 28 or 30 inches differences in rate of growth between the seven groups become unimportant. For these larger trees the factors of relative values exposed to the risk of loss and their seed bearing ability should govern the choice in marking.

It is apparent from Fig. 1 that age is the most important factor to be considered. Crown development and crown class differences are far more important in the young and sub-mature than in the mature and over-mature age classes.

A summary of the growth produced by the above stand is given in Table 4. The Class 1 trees, which represented but 29.4 per cent of the residual stand, produced 57.7 per cent of the total growth and maintained the highest annual rate, 3.06 per cent. The Class 2 trees grew only half as rapidly. While the Class 3 trees have not justified their retention from the standpoint of growth, the annual rate of nearly one per cent is fairly good, and increase in value justifies reserving a considerable proportion of such trees. Little can be said in defense of the reservation of nearly one-fourth of the stand in Class 4 and 5 trees.

Table 4.

Per cent of basal area represented by each tree class, the per cent of total growth produced, and the annual rate maintained by each tree class between 1910 and 1925. Western yellow pine, Stanislaus, Plots 2, 3, and 4. Site I. Cut over in 1910.

Tree Class	1	2	3	4	5	6	7	Total
Per cent of total basal area in class	29.4	11.4	27.9	5.1	18.8	3.7	3.7	100.0
Per cent of growth produced	57.7	11.2	17.8	1.9	4.3	5.6	1.5	100.0
Annual growth rate	3.06	1.53	0.98	0.59	0.35	2.34	0.65	1.56

A similar relationship is shown graphically for a much larger area in Figure 2.

It should be remembered that the foregoing growth comparisons include the acceleration due to release by cutting, which should have culminated within fifteen years after the thinning. The trees which were subordinate in the original stand have not generally improved sufficiently to equal the rates maintained by former dominants. It is usual for higher classes to decline to subordinate classes, but extremely exceptional for the reverse process to occur. Acceleration of growth is a minor consideration in the prevailing type of cutting with its tendency toward grouping of reserves. It is better to reserve trees already dominant than to rely upon the enhancement of increment in understory trees.

Comparisons of Losses

The ultimate success of marking is dependent upon both potential growth rates, as discussed above, and upon survival of the growing stock.

Out of a total of 4669 trees over four inches in diameter on the plots used in the following summary which were alive after cutting in 1910 and could be definitely assigned to their proper tree classes, 172 died between 1910 and 1925. The distribution of the total trees by classes in 1910 and the distribution of the dead trees by classes are shown below (Table 5). The lower line of figures shows the relative liability to loss, or the ratio of occurrence in the losses to occurrence in the stand as a whole[2].

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2. Direct expression of loss rates in per cent would be misleading because several additional dead trees could not be assigned to their proper tree classes.

Table 5.

Tree Class	1	2	3	4	5	6	7	Total
Per cent of trees in Class - 1910	34.0	8.4	15.4	6.6	5.5	16.5	13.6	100.0
Per cent of dead trees in class	4.7	13.4	11.6	11.6	6.4	23.2	29.1	100.0
Ratio: Per cent of dead / Per cent of total	0.14	1.60	0.75	1.76	1.16	1.41	2.14	1.00

On a numerical basis it is evident that the Class 1 trees are the lowest risk. They are represented in the losses only about one-seventh as

frequently as in the stand as a whole. The liability to loss is from five to fifteen times greater for the other classes than for the first. Class 7 has the highest risk factor, followed by Classes 4, 2, 6, 5, and 3. It is fortunate for the reserve policy that the Class 3 trees have the lowest risk factor of any class except the first.

The significance of the loss figures is more clearly brought out through basal area comparisons. The above 4669 trees had a basal area of 7855.64 sq. ft. in 1910. The basal area of the 172 trees which died was 334.99 sq. ft. in 1910. The distribution by tree classes was as follows.

Table 6.

Tree Class	1	2	3	4	5	6	7	Total
Percent of total B.A. in class	24.9	5.7	35.0	7.8	19.5	3.2	3.9	100.0
Per cent total loss in class	5.2	5.6	26.7	14.5	33.6	2.3	12.1	100.0
Ratio: Per cent of total loss / Per cent of total B.A.	0.21	0.98	0.75	1.86	1.72	0.72	3.10	1.00

On this basis the Class 1 trees still represent much the lowest risk, followed by Classes 6, 3, 2, 5, 4, and 7. The greatest actual losses occurred in Classes 3, 4, and 5, partly because the trees in these groups are large and formed a considerable portion of the reserve, and partly because of a higher loss rate, especially in the case of Class 4 and 5 trees, as indicated by the high ratios in the lower line of Table 6. (See also Fig 2.) If the relative risks were expressed in terms of value exposed to loss, rather than basal area, the disparity would be much greater, since Classes 3, 4, and 5 produce the highest percentage of upper grade lumber.

The greatest single cause of mortality was insects (Dendroctonus) which killed 61, or 35 per cent of the 172 trees, accounting for 50 per cent of the basal area loss.

The distribution of ~~insect~~ losses by tree classes as compared with losses from other causes was as follows:

Table 7.

Tree Class	1	2	3	4	5	6	7	Total
Per cent of insect loss in class	2.4	5.4	14.6	16.2	48.7	1.1	10.6	100.0
Per cent of other losses in class	7.0	5.8	38.6	12.8	18.6	3.5	13.7	100.0

Only a small part of the loss from insects occurred in the younger tree classes 1, 2 and 6, the greatest portion, nearly half the total, being in Class 5. The relative risk of loss from insects in the various classes may be expressed by the following ratios, derived by dividing the percentage of the total basal area loss occurring in each class by the percentage each class forms of the total basal area of the stand. For comparison similar ratios for other causes of loss are also shown.

Table 8.

Tree Class	1	2	3	4	5	6	7	Total
Ratio: % of insect loss in class / % of stand in class	0.09	0.95	0.42	2.08	2.50	0.34	2.72	1.00
Ratio: % of other losses in class / % of stand in class	0.28	1.02	1.10	1.64	0.95	1.09	3.82	1.00

The probability of insect loss is greatest in Class 7. Such trees appear 2.72 times as frequently in the losses as they do in the stand as a whole. The high factors for Classes 4 and 5 are particularly significant because of the high grade material contained in trees of these types. The above comparisons indicate that only trees of Classes 4 and 5 are more subject to losses from insects than from other causes. For Class 5 trees the risk from insects is almost three times as great as from other causes. It is worth noting that Class 3 trees, which should properly make up the bulk of the better quality of timber reserved, are apparently less liable to damage from insects than from other causes. These relationships are shown graphically in Figure 3.

The above comparisons in basal area show the combined results of relative susceptibility and amount of timber exposed to loss. The selective tendency alone is more strikingly indicated by numerical comparisons as shown graphically in Figure 3. The small crowned mature codominants of Class 4 are indicated to be the most liable to insect damage.

The above indicated relative susceptibility of various tree types

to killing by the western pine beetle are in close agreement with some carefully controlled experiments being conducted by H. L. Persons of the Bureau of Entomology (11). The elimination of susceptible trees in cutting would doubtless lessen endemic insect damage, the most important cause of loss on cut-over areas.

Comparisons of Seed Bearing

The seed bearing capacity of forest trees has been shown by many investigators to be affected by a large number of environmental and inherent factors. In the present study the aim has been to determine how well the proposed tree classes integrate seed bearing capacity without attempting to determine the more fundamental biological influences involved. Even to this extent the present results are but tentative.

The physical difficulties encountered in a quantitative determination of the amount of seed borne are obvious. Unfortunately, too, there have been no really heavy general seed crops since the trees have been under observation, that would permit comparison of seed bearing by similar tree types under different site conditions, or the consistency of bearing by the same trees from year to year. The data available necessarily limits comparisons to single localities and certain years. There are, however, certain outstanding differences which justify consideration. At present it is impossible to go further than to indicate what types of trees appear to be the best seed bearers. Determination of the exact quantity and quality of seed that is produced and remains undestroyed by insects, rodents, etc., must be left for further study.

The procedure has been to count with binoculars the number of mature cones borne by trees of various types. Observation indicates that occasionally a potentially good seed bearer sets a heavy crop of fertile

cones, all of which are destroyed before maturity by cone beetles or rodents. For all species except sugar pine, it has been found impossible to count the immature cones early enough to avoid these losses. In the absence of exact knowledge it is assumed for the present that such damage is not restricted to any particular tree class, and that the figures presented are comparable.

Under similar conditions of site, the major factors influencing seed bearing appear to be age, position in the crown canopy, and crown development. Since the size attained is closely correlated with age, crown class, and crown development, it is to be expected that there exists a close relation between diameter and seed bearing capacity. This relation is shown in the accompanying chart (Fig. 4) for three localities in certain years.

Below eight inches a negligible percentage of the trees bore cones. Between 8 and 24 or 26 inches the proportion of trees bearing cones increases rapidly. Above 26 inches practically all the trees bore some cones. At 20 inches, the size ordinarily regarded as representing satisfactory seed trees (14) from 50 to 90 per cent of the trees bore seed in these years.

It is well known that for many species there is a fairly definite alternation of seed years and years of rest. Thus on the Lassen area only 62.5 per cent of the trees bore seed in both the seasons of 1921 and 1926. Were records for a number of years available, they would doubtless show a much higher percentage capable of seed bearing than the chart indicates. In the seasons given the seed crops were never exceptional. In heavy seed years the proportion bearing cones would be greater than indicated.

The number of cones borne also varies greatly with diameter, an indirect integration of age and other factors. The number of cones per tree for two areas is shown in Figure 5 for the year 1926. The difference between the two curves illustrates the great local variation in the seed crop of the

same season, the Lassen area being situated 160 miles north of the Stanislaus. These curves indicate that, in years of ordinary seed crops, at least, rather large trees are necessary for the production of considerable quantities of seed. While 60 per cent or more of the 20-inch trees may be capable of bearing seed, the number of cones borne is relatively small.

The foregoing discussion indicates that the best seed trees will be found in the tree classes represented by the larger sizes. The following summary of typical data from the Feather River group of plots makes this clearer (Table 9.).

Table 9.

Class	1	2	3	4	5	6	7	Total
No. trees	214	84	154	52	4	97	27	632
Average D. B. H.	15.0	13.5	25.7	20.4	38.8	7.3	11.4	—
Per cent bearing	22.9	6.5	55.8	40.4	100.0	1.0	11.1	27.9

The indicated differences are doubtless a result of the combined influences of age, crown development and position, or size. Comparison for a given size class is impossible because, in the nature of things, there is no one size class in which all the tree classes are well represented. It is apparent, however, that seed bearing trees will most frequently be found among the principal trees of Classes 1, 3, 4, and 5 and that classes 2, 6 and 7 provide an insignificant number of seed bearers. This relationship has been well established by a considerable number of investigations elsewhere (15)(16).

As to quantities of seed per tree, the present scanty data and the more ample results of other investigators (10) leaves little doubt that trees of the types found in Classes 2, 6, and 7 bear but few cones. The largest numbers of cones per tree thus far counted were for trees of Class 3.

Summary

A tree or thrift class grouping applicable to selection stands is needed on which to base marking principles, to permit correlation of growth studies, and investigations of insect losses, fire damage, etc. The conventional crown classes, and other tree classifications for even-aged stands are unsuitable for all-aged mixed forests.

On the basis of observations of permanent sample plots over a period of fifteen years a tree grouping is proposed comprising seven classes defined by combinations of easily observed factors influencing vigor. The major factors considered are age, degree of dominance, and crown development. Confirmatory indications of relative vigor considered are form of top, color and density of foliage, character of bark, size, etc.

The seven classes are described as follows:

1. Young or thrifty mature trees (80 - 150 years); isolated or dominant (rarely codominant); crown large; top pointed; foliage dark green and dense; bark dark in color and finely fissured.

2. Similar to the above but with small crowns, usually codominant.

3. Mature trees (150-300 years), isolated or dominant (rarely codominant); crown large; Top round; foliage moderately dense; bark light in color, fairly smooth with moderate sized plates.

4. Similar to 3, but with small crowns. Usually codominant.

5. Overmature trees (over 300 years); dominant or codominant; top flat; foliage thin; bark light yellow, with large smooth plates.

6. Young or thrifty mature intermediate and suppressed trees.

7. Mature or overmature intermediate and suppressed trees.

Defective trees should be considered on the basis of merchantability and liability to loss rather than rate of growth.

Marked differences in rates of growth demonstrate that the above grouping is a reliable integration of vigor.

Classes 1, 2, and 6 trees grow most rapidly and their retention involves the smallest percentage of merchantable values.

Class 1 trees grow at the best rate and have the lowest loss liability factor. They are the least susceptible to insect attacks. They are good seed bearers when of sufficient size. The present value of such trees is comparatively low. They should always be retained when sound.

Class 2 trees make fair growth but are rather liable to loss and are poor seed bearers. They should be marked in peference to Class 1 trees.

Class 3 trees grow rather slowly but their liability to loss is low. They are good seed bearers. Such trees are desirable for retention as seed trees or to constitute a moderate reserve of high quality material for increase in value and to make a second cutting feasible in a reasonably short time.

Class 4 and 5 trees produce practically no growth even on the best sites. Their liability to loss is high. Their retention involves the risk of a large investment in high quality timber. They should practically always be cut.

Class 6 and 7 trees are usually too small to be merchantable. Class 6 trees grow fairly well and give promise of later development if

released. They bear practically no seed. Class 7 trees are undesirable from every standpoint and should be cut whenever possible.

To maintain the best average stand growth no trees over 30 inches in diameter should be reserved of any class even on the best sites. Except in Classes 1, 2 and 6 little is to be gained by retaining the smaller trees in preference to the larger, except in reducing the investment exposed to the risk of loss.

Seed trees should be of Classes 1 or 3 and from 20 to 30 inches in diameter.

Literature Referred to in the Text.

1. Dunning, D.

   The relation of crown size and character to rate of growth and response to cutting in western yellow pine. Journ. For. v. 20, No. 4. pp. 379-389. 1922.

2. ____________

   Some results of cutting in the Sierra forests of California. U. S. D. A. Bull. 1176. 1923.

3. Hanzlik, E. J.

   Tree classification in Sweden. Journ. For. v. 22, No. 2. pp. 175-177. 1924.

4. Heck, C. R. von. Freie Durch-forstung. Berlin, Julius Springer. 115 p. 1904.

5. Japing. -

   Ueber das Wachstum der Kraftischen Stammklassen im Verlauf einer zehnjährigen Zuwachsperiode. Zeitsch. für Forst-und Jagdw. 43. p. 663-686. Sept. 1911.

6. Kraft, G.

   Beiträge zur Lehre von den Durchforstungen, Schlagstellungen und Lichtungshieben. Hanover, Klingworth. 147 p. 1884.

7. Krauch, Hermann

The determination of increment in cut-over stands of western yellow pine in Arizona. Jour. Agr. Res. v. 32, No. 6. pp. 501-541. 1926.

8. Lakari, O. J.

Tutkimuksia männyn muodosta. (German summary: Untersuchungen über die Form der Kiefer.) Comm. ex. Inst. Quest. Forest. Finlandiae. Ed. 3. p. 1-8. 1920.

9. Lorey, Tuisco

Handbuch der Forstwissenschaft. V. p. 172. Tubingen, H. Laupp. 1912.

10. Pearson, G. A.

Natural reproduction of western yellow pine in the Southwest. U. S. D. A. Bull. 1105. 143 p. 1923.

11. Persons, H. L.

Title?

Ms report.

12. Price, J. H.

Relation of quality of lumber produced to percentage of the stand cut. Timberman, May, 1924.

13. Schotte, Gunnar

Om gallringsförsök. (Über Durchforstungsversuche.) Meddelanden fr. statens skogsförsöksanstalt, H. 9. Stockholm, 1912.

14. Show, S. B.

Timber growing and logging practice in the California pine region. U. S. D. A. Bull. 1402. 1926.

15. Soboleff, A.

Verteilung des Samenertrags bei der Fichte nach den Bäumen der Kraftischen Stammklassen. Vergl. Centralbl. f.d. ges. Forstw. p. 137. 1909.

16. Zon, R.

Seed production of western white pine. U. S. For. Serv. Bull. 210. 1915.

DUNNING'S PROPOSED TREE CLASSIFICATION

	Class I	Class II	Class III	Class IV	Class V	Class VI	Class VII
Age Class	Young or thrifty mat. 50-150 yrs.	Young or thrifty mat. 50-150 yrs	Mature 150-300 years	Mature 50-150 years	Over-mature. 300 yrs.	Young or thrifty mature	Mature or overmature
Position	Isolated or dominant	Usually co-dominant	Isolated or dominant	Usually codominant	Isolated or dominant	Interm. or supr.	Interm. or supr.
Crown L.	65% or more of tot. ht.	65% of tot. ht.	65% or more	65% tot. ht.	Any size	Any size, usually small	Any size,- usually small
Crown Width	Average or wider	Average or narrower	Average or wider	Average or narrower	Any size	Any size	Any size - usually small
Form of Top	Pointed	Pointed	Rnd. because of slow ht. growth	Round	Flat	Round or Pointed	Flat
Vigor	Good	Good or moderate	Moderate	Moderate or poor	Poor	Moderate or Poor	Poor
Diameter	Rarely over 30"	24"	18"- 40" dep. on site	Except for small poorly developed crownd and smaller size, similar to Class III	Largest in stand	12" -14"	Rarely over 18"
Bark	Dk. B. roughly fis. into ridges or small	Same as Class I	Lt. B. or yel. mod. lg. smooth pl.		Lt. yel. wide long smooth plates	Dark and rough	Light in color thin and small
Foliage	Rich G. dense needles lg. coarse	" "	Less dense than Class I		Pale green thin needles sh. tufty on ends of twigs		Excess, thin
Term Buds	Large	" "	Slow ht. growth		Rarely dist.	Some Ht. growth	Rarely dist.
Annual Whorls of branches	Still dist. except Lower crown branches, horizontal or upward curving.	Crowns smaller or less dense than Class I	Nodes indistinct branches horizontal or drooping		Drooping, gnarled, crooked	Evident internodes short	Gnarled, drooping

APPLICATION OF CLASSIFICATION TO

MARKING

Classes 1, 2 and 6 most rapid growing.

Retention involves smallest per cent merchantable volume Class I. Grow at best rate and have lowest loss liability factor. Least susceptible to insect attacks. Good seed bearers when of sufficient size. Always retain when sound.

Class 2 - Fair growth. - liable to loss - poor seed bearers - Mark in preference to Class I.

Class 3 - Slow growth, liable to loss low. Good seed bearers. Desirable to retain as seedtrees. Quality increment reserve where there will be cut in comparative short time.

Classes 4 and 5 - Practically no growth even on best sites. Loss liability high. - too much risk to hold. Practically always cut.

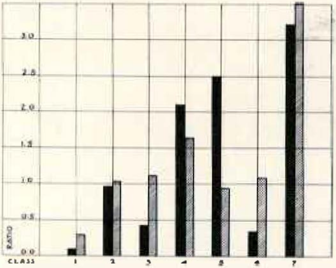
Classes 6 and 7 - Too small to be merchantable. Class 6 grow fairly well if released. Produce practically no seed. Class 7 should be cut wherever possible.

To maintain best average stand growth no trees over 30" in diamter in any class should be reserved even on best sites. Except in Classes I, II and VI little is to be gained by retaining the smaller trees in preference to larger, except in reducing the investment exposed to the risk of loss. Seed trees should be of classes 1 or 3,-from 20" - 30" D.B.H.

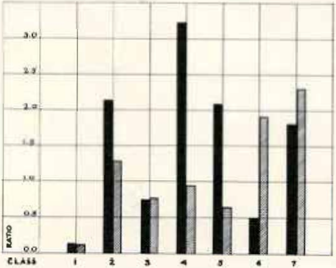
GRAPHS

FIG. 3

RATIO OF OCCURRENCE OF TREE CLASSES IN INSECT LOSSES ▬ AND IN OTHER LOSSES ▨ TO OCCURRENCE IN STAND.



BASAL AREA



NUMBER OF TREES

FIG. 4

WESTERN YELLOW PINE

PER CENT OF TREES BEARING CONES

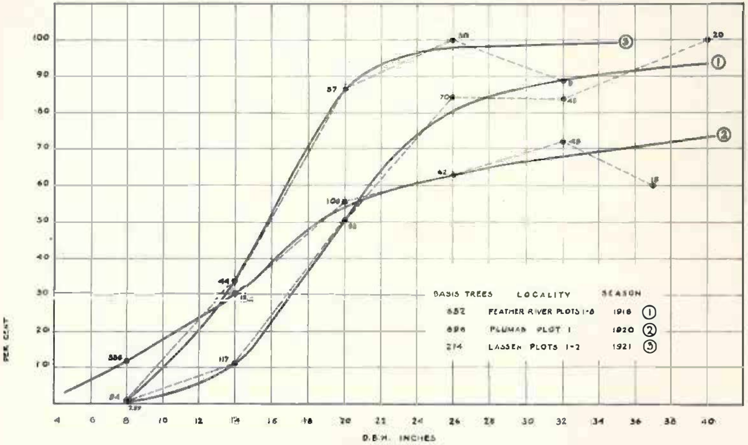
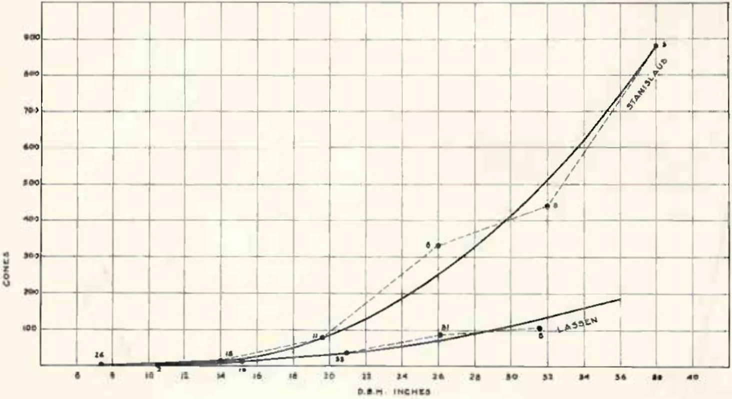


FIG. 5

WESTERN YELLOW PINE

NUMBER OF CONES PER TREE 1926.

LASSEN PLOTS 1 & 2 , STANISLAUS PLOT 5.



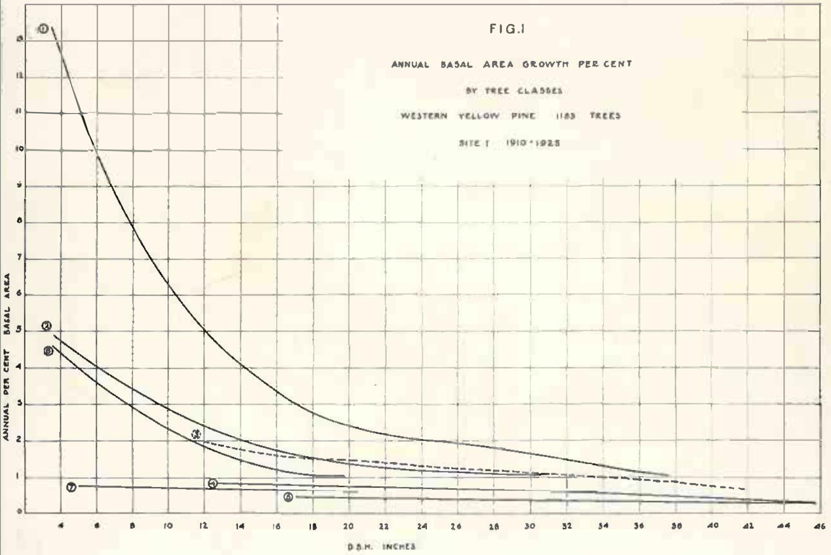


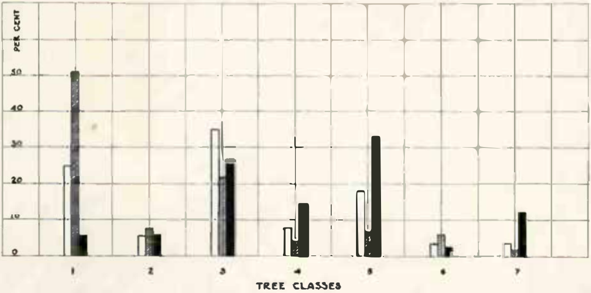
FIG.1
ANNUAL BASAL AREA GROWTH PER CENT
BY TREE CLASSES
WESTERN YELLOW PINE 1183 TREES
SITE I 1910-1925
ANNUAL PER CENT BASAL AREA
D.B.H. INCHES

FIG. 2

PER CENT OF TOTAL BASAL AREA IN EACH TREE CLASS, PER CENT OF TOTAL GROWTH PRODUCED BY EACH AND PER CENT OF TOTAL LOSS WHICH WAS IN EACH CLASS.

BASIS 4669 TREES. 7865.64 SQ.FT.

1910-1925.



LEGEND

PER CENT OF STAND

PERCENT OF GROWTH

PER CENT OF LOSSES